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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
09/912,558	07/26/2001	Ronald A. Weimer	M4065.0319/P319-A	5990
24998	7590	03/17/2004	EXAMINER	
DICKSTEIN SHAPIRO MORIN & OSHINSKY LLP 2101 L STREET NW WASHINGTON, DC 20037-1526			KIELIN, ERIK J	
		ART UNIT	PAPER NUMBER	
		2813		

DATE MAILED: 03/17/2004

Please find below and/or attached an Office communication concerning this application or proceeding.

Office Action Summary

Application No.	09/912,558	Applicant(s)	WEIMER ET AL.
Examiner	Erik Kielin	Art Unit	2813

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --
Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) FROM
THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If the period for reply specified above is less than thirty (30) days, a reply within the statutory minimum of thirty (30) days will be considered timely.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1) Responsive to communication(s) filed on 05 January 2004.
2a) This action is FINAL. 2b) This action is non-final.
3) Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims

4) Claim(s) 13, 14, 16-25 and 41-43 is/are pending in the application.
4a) Of the above claim(s) 18-25, 41 and 43 is/are withdrawn from consideration.
5) Claim(s) _____ is/are allowed.
6) Claim(s) 13, 14, 16, 17 and 42 is/are rejected.
7) Claim(s) _____ is/are objected to.
8) Claim(s) _____ are subject to restriction and/or election requirement.

Application Papers

9) The specification is objected to by the Examiner.
10) The drawing(s) filed on _____ is/are: a) accepted or b) objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).
11) The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

Priority under 35 U.S.C. § 119

12) Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
a) All b) Some * c) None of:
1. Certified copies of the priority documents have been received.
2. Certified copies of the priority documents have been received in Application No. _____.
3. Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) Notice of References Cited (PTO-892)
2) Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) Information Disclosure Statement(s) (PTO-1449 or PTO/SB/08)
Paper No(s)/Mail Date _____

4) Interview Summary (PTO-413)
Paper No(s)/Mail Date. _____
5) Notice of Informal Patent Application (PTO-152)
6) Other: _____

DETAILED ACTION

Continued Examination Under 37 CFR 1.114

1. A request for continued examination under 37 CFR 1.114, including the fee set forth in 37 CFR 1.17(e), was filed in this application after final rejection. Since this application is eligible for continued examination under 37 CFR 1.114, and the fee set forth in 37 CFR 1.17(e) has been timely paid, the finality of the previous Office action has been withdrawn pursuant to 37 CFR 1.114. Applicant's submission filed on 20 October 2003 has been entered.

Election/Restrictions

2. Applicant's election without traverse of the invention of Group I in Paper filed 2 January 2004 is acknowledged.
3. Claims 41 and 43 are withdrawn from further consideration pursuant to 37 CFR 1.142(b) as being drawn to nonelected inventions, there being no allowable generic or linking claim.
4. Claims 13, 14, 16, 17, and 42 are elected.

Claim Rejections - 35 USC § 112

5. The following is a quotation of the first paragraph of 35 U.S.C. 112:

The specification shall contain a written description of the invention, and of the manner and process of making and using it, in such full, clear, concise, and exact terms as to enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to make and use the same and shall set forth the best mode contemplated by the inventor of carrying out his invention.
6. Claims 13, 14, 16, and 17 are rejected under 35 U.S.C. 112, first paragraph, because the specification, while being enabling for a ratio of **steam** relative to other gases in the chamber being from about 0.1 to 0.5, does not reasonably provide enablement for the ratio of the **mixture**

of hydrogen and oxygen relative to other gases in the chamber being from about 0.1 to 0.5. The specification does not enable any person skilled in the art to which it pertains, or with which it is most nearly connected, to use the invention commensurate in scope with these claims. See the instant specification at p. 8, lines 18-25.

There exists no written description to support claim 13 as presently amended. The specification addresses the amount of steam relative to the other gases --not the amount of hydrogen and oxygen relative to the other gases. The stoichiometry of H₂ plus O₂ to form H₂O is 2 H₂ to 1 O₂ to form 2 H₂O (steam in the instant case). Unless the ratio of H₂ to O₂ is specifically to 2 to 1, then there exist "other gases" in the chamber, specifically excess O₂ or H₂. In the instant specification, Applicant has indicated that the ratio of H₂ to O₂ is from 0.1 to 0.8. This requires the presence of excess oxygen which contributes some unknown amount to the "other gases in the chamber." Because no written description support exists for how the mixture of hydrogen and oxygen should vary with respect to the other gases in the chamber, one of ordinary skill would not be able to practice the invention as presently claimed.

The remaining claims are rejected for depending from the above rejected claims.

7. Claims 13, 14, 16, and 17 are rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the written description requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to reasonably convey to one skilled in the relevant art that the inventor(s), at the time the application was filed, had possession of the claimed invention.

There exists no written description to support claim 13 as presently amended to include the limitation that the ratio of the **mixture of hydrogen and oxygen** relative to other gases in the chamber being from about 0.1 to 0.5. The reasons are as above.

The remaining claims are rejected for depending from the above rejected claims.

8. Claim 42 is rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the enablement requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention.

Claim 42 is not enabled because the specification fails to indicate how the wet oxidation would be carried out using in situ reaction of hydrogen and oxygen at a pressure of about 1 atmosphere. The pressure of about 1 atmosphere cannot be maintained because there will necessarily be an explosion/detonation under the conditions presently disclosed. Rationale follows.

Claim 42 requires the pressure in the chamber to be "about atmospheric pressure." Given the claimed ratio of hydrogen to oxygen claimed to be 0.1 to 0.8 (that is the equivalent of 90 mol% O₂ in H₂ down to 10 mol% O₂ in H₂) and, as stated in the **specification at p. 8, lines 13-25**, that the ratio of steam to other gases is preferably 0.1 to 0.5 when such H₂ - O₂ mixture is used. Given the stoichiometry of the reaction between hydrogen and oxygen to form water: 2H₂ + O₂ → 2H₂O, the concentration of hydrogen must be 0.1 or 10% (or 76 Torr at the claimed 1 atmosphere [760Torr] of pressure) relative to the other gases, in order to produce steam in a ratio of 0.1 relative to the other gases. The explosion concentration limits for hydrogen in air are 4.1% to 74.2%. (See Appendix A: obtained from <http://toxnet.nlm.nih.gov/cgi-bin/sis/search> which has

Art Unit: 2813

the explosion limits for hydrogen in air.) Accordingly, there will necessarily be an explosion in the entire disclosed preferred range of 0.1 to 0.5 steam to other gases, disclosed in the instant specification. Fig. 7 of Miner shows that the detonation of hydrogen with oxygen **increases** the pressure. In the examples shown in Fig. 7, shows that 10% hydrogen (the 90% oxygen in the horizontal axis) only 15 Torr lead to an increase in pressure of 0.5 atm (380 Torr) that is a 380/15-fold or about 25-fold increase in pressure. Accordingly, the pressure presently claimed would far exceed 1 atmosphere.

Further in this regard, the instant specification at p. 9, lines 2-5 teaches away from such high pressures when H₂ and O₂ mixtures are used to generate the steam, stating,

“In general, the pressure can be at about atmospheric pressure, although if the H₂ and O₂ gases are combined in the chamber 50, then the **pressure should be kept lower, for example, around 1 millitorr.**”
(Emphasis added.)

This pressure is 0.001 Torr. It begs the question as to why, now Applicant would claim that the pressure should be 760 Torr (1 atm), or 760,000 times the pressure indicated in the specification.

Accordingly claim 42 is not enabled because specification fails to provide conditions capable of using an explosive mixture of H₂ and O₂ gases at 1 atmosphere to perform an oxidation maintained at 1 atmosphere.

Claim Rejections - 35 USC § 102

9. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(e) the invention was described in (1) an application for patent, published under section 122(b), by another filed in the United States before the invention by the applicant for patent or (2) a patent granted on an application for

patent by another filed in the United States before the invention by the applicant for patent, except that an international application filed under the treaty defined in section 351(a) shall have the effects for purposes of this subsection of an application filed in the United States only if the international application designated the United States and was published under Article 21(2) of such treaty in the English language.

10. Claims 13, 14, 17, and 42 are rejected under 35 U.S.C. 102(e) as being anticipated by US 6,114,258 (Miner et al.).

Regarding independent claims 13 and 42, Miner discloses a method of forming a gate dielectric layer on a substrate comprising the steps of

depositing a dielectric film 105 over an active region of a semiconductor substrate 100 to from part of a gate of a transistor (col. 2, lines 20-22), wherein the dielectric film is, *inter alia*, silicon nitride (col. 4, lines 31-36; Figs. 1-3) --as further limited in claim 17; and

subjecting the dielectric film to a wet oxidation with steam process to raise the oxygen content of said dielectric layer, wherein the steam is provided by heating a mixture of hydrogen and oxygen gases in a rapid thermal process chamber at a temperature greater than 450 °C, particularly 400 °C to 1200 °C (col. 8, lines 13-32) and specific examples of 600 °C (col. 9, line 35) and 950 °C (col. 8, lines 44-56) for a period of 30 to 120 seconds (Figs. 8a-8b; col. 10, lines 3-4)--as further limited by instant claim 14. The H₂ to O₂ ratio is 0.5/1 or less, for oxygen-rich mixtures (col. 8, lines 61-62) which falls within the claimed H₂ to O₂ ratio of 0.1 to 0.8. The ratio of "said mixture" (i.e. steam) relative to the other gases in the chamber overlaps the range of 0.1 to 0.5 and is therefore anticipated (col. 8, line 57 to col. 9, line 23).

Further regarding claim 42, the pressure is potentially about atmospheric pressure at least during a detonation of the hydrogen and oxygen gases (col. 8, line 44 to line 56).

Claim Rejections - 35 USC § 103

11. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

(a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

12. Claims 13, 14, 16, and 17 are rejected under 35 U.S.C. 103(a) as being unpatentable over the article **Luan**, et al. "Ultra thin high quality Ta₂O₅ gate dielectric prepared by in-situ rapid thermal processing" Electron Devices Meeting, held 6-9 December 1998, IEDM '98 Technical Digest, pp. 609-612 in view of US 6,063,698 (**Tseng** et al.).

Regarding independent claims 13, 41, 42, and 43 **Luan** discloses a method of forming a gate dielectric layer on a substrate comprising the steps of depositing a dielectric film over an active region of a semiconductor substrate to form part of a gate of a transistor, wherein the dielectric film is tantalum oxide (Ta₂O₅), as further limited in claim 17, having the inherent property of a dielectric constant of "at least about 25" (Introduction), as further limited in instant claim 16; and

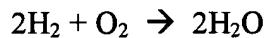
subjecting the dielectric film to a wet oxidation with a steam process to "improve film quality and reduce leakage current" by heating a mixture of hydrogen and oxygen gases using rapid thermal processing (RTP) and therefore occurring, by definition, in a RTP chamber, at a temperature of 600 °C for a period of about 40-50 seconds (Fig. 1), and wherein the pressure of said rapid thermal process chamber is inherently less than atmospheric pressure. (See whole **Luan** article which is very brief.)

While Luan is silent as to the pressure --suggesting that the pressure is unimportant to the process, just as does Applicant-- it is, nonetheless, seen to be inherent that the pressure in the RTP chamber is less than atmospheric because of the stoichiometry of the reaction between hydrogen and oxygen to form water: $2\text{H}_2 + \text{O}_2 \rightarrow 2\text{H}_2\text{O}$. Because there is a net decrease in number of molecules (from 3 to 2), and because pressure is directly proportional to the number of molecules present by the ideal gas law $\text{PV} = \text{nRT}$, where P is the pressure, V is the volume, "n" reflects the number of molecules (in moles), R is the ideal gas constant, and T is the temperature, the pressure necessarily decreases upon the reaction of hydrogen with oxygen. Accordingly, the pressure is less than atmospheric, since the pressure decreases in the RTP chamber. Moreover, the specification points out that atmospheric pressure or 1 milliTorr are sufficient pressures, indicating that the pressure is not critical to achieving the objective of increasing the oxygen content of the dielectric layer and thereby reducing leakage current. (See MPEP 2112.)

It is also seen to be inherent that the oxygen content of the dielectric layer is increased because the film quality is improved and the leakage current reduced, as admitted in the instant specification to be known in the art and to be inherently provided by a wet oxidation process (instant specification, Abstract; p. 1, lines 28-32; p. 3, lines 13-20, p. 4, lines 9-13, etcetera.) Since Luan teaches the leakage current is reduced by performing a wet oxidation using hydrogen and oxygen, it is seen to be inherent based upon Applicant's admissions of record, that the oxygen content of the dielectric layer is increased. (See MPEP 2112.)

Luan does not teach a wet oxidation temperature in the range of 750-950 °C or a ratio of H₂ to O₂ of about 0.1 to 0.8 (i.e. 10% to 80% H₂) or that the ratio of steam to the other gases in the mixture is 0.1 to 0.5.

Tseng teaches a process virtually identical to **Luan** of forming a tantalum oxide gate dielectric **14** on a semiconductor substrate **12** and then wet oxidizing by heating a mixture of H₂ and O₂ to a temperatures of 750-850 °C, wherein the H₂ to O₂ ratio is about 0.03 to about 0.09 (col. 6, lines 58-63) to beneficially “eradicate trap sites **16** and **18**” (col. 6, lines 39-57), which is about 0.1. The **Tseng** teaches that the flow rate of O₂ is 20 liters per minute and that of the diluted H₂ is 10 liters per minute, wherein the amount of hydrogen in the mixture is 3% to 9%. (See also Abstract; col. 5, line 54 to col. 6, line 17.) Given that the reaction between H₂ and O₂ is as follows:



Given this stoichiometry, when the hydrogen reacts with the oxygen to form steam in accordance with the teaching in **Tseng**, 9% of the oxygen present will react to form water. The net result is 0.09 times 30 liters per minute which is 2.7 liters per minute of water as steam. Also given the stoichiometry, the total volume decreases because 3 molecules are converted to 2 molecules. This means that there is a net loss of 1/3 times 2.7 liters per minute which is a loss of 0.9 liters per minute. So the total volumetric flow rate is 30 - 0.9 = 29.1 liters per minute. So the final reacted mixture yields steam at 2.7 liters per minute in 29.1 liters per minute of total gas mixture which is 2.7 divided by 29.1 liters per minute which is a ratio of steam 0.093 relative to the total gas mixture which is greater than 0.005 and which is about 0.1 relative to the other gases in the mixture, which overlaps the presently claimed amounts.

It would have been obvious to one of ordinary skill at the time of the invention to modify the method of **Luan** to use the temperature and ratio of hydrogen to oxygen taught by **Tseng** in order to beneficially reduce the trap sites and improve the dielectric as taught by **Tseng** and to further reduce the leakage current as taught by **Luan** which is a direct measure of the reduction of trap sites, as taught by **Tseng** (Abstract; col. 4, first paragraph)--especially since the methods are virtually the same.

Further in this regard, it would be a matter of routine optimization to determine the optimum ratio of hydrogen to oxygen, since **Luan** clearly teaches the use of hydrogen and oxygen therefore expressly indicating some ratio. It has been held that claimed ranges of a result effective variable, which do not overlap the prior art ranges, are unpatentable unless they produce a new and unexpected result which is different in kind and not merely in degree from the results of the prior art. *In re Huang*, 40 USPQ2d 1685, 1688(Fed. Cir. 1996). In the instant case, Applicant has not provided any evidence that the claimed ratio provides unexpected results relative to that used in **Luan** alone or **Luan** in view of **Tseng** --especially since **Luan** only fails to indicate what the ratio of hydrogen to oxygen is, such that one of ordinary skill would be motivated to optimize the ratio to get the best results. Furthermore, the temperature would also amount to routine optimization with consideration to **Tseng** because, it has been held that claimed ranges of a result effective variable, which do not overlap the prior art ranges, are unpatentable unless they produce a new and unexpected result which is different in kind and not merely in degree from the results of the prior art. *In re Huang*, 40 USPQ2d 1685, 1688(Fed. Cir. 1996).

Response to Arguments

13. Applicant's arguments filed 29 October 2003 have been fully considered but they are not persuasive.

Applicant argues that Miner does not teach each of the features of the instant invention. Examiner respectfully disagrees for reasons already presented in the rejection of the claims above.

Applicant argues that Luan does not teach wet oxidation in steam. Applicant fails to provide evidence that H₂ and O₂ would not react at 600 °C to form steam. This is merely an argument that Applicant's disclosed invention does not work. It is clear that Applicant fails to know the chemistry of hydrogen and oxygen. Applicant indicates in the specification that 450 °C is sufficient to enable the H₂ and O₂ to react.

Applicant argues that Luan teaches virtually nothing. Examiner respectfully disagrees for reasons of record as recited in the rejection above, the limitations of the claims as recited in the rejection above, incorporated herein in their entirety.

Applicant argues the Luan and Tseng teach away from each other because the temperatures and times are different. Examiner respectfully disagrees. Nowhere does Luan teach that 750 °C will not work. Nowhere does Tseng teach that 600 °C will not work. The temperature in Luan is exemplary. If anything, Tseng teaches that more than one temperature is usable. Similarly, simply because the oxidation times are different is no indication that one or the other will not work. Tseng uses a furnace which requires time to heat up. Luan uses a **rapid** thermal process chamber. The oxidation methods are complementary. The difference is that rapid thermal oxidation is merely faster. Accordingly one of ordinary skill would not be even slightly deterred

in combining the teaching of the H₂/O₂ ratios and the ratio of steam in Tseng as those ratios in Luan since Luan simply doesn't mention those ratios. Applicant is reminded that a teaching away is an expression that a thing or condition (i.e. temperature, pressure, time) **will not work** -- not that they are simply different. Luan and Tseng form exactly the same tantalum oxide film in the same manner (i.e. deposition of Ta₂O₅ followed by wet oxidation using a mixture of H₂ and O₂) for the same use, as a gate dielectric. Accordingly, the teachings of Luan and Tseng are properly combinable.

Applicant argues that Luan uses an aluminum gate and so would not use a the wet oxidation temperature of 750 °C of Tseng, as per the teaching in Tseng that temperatures above 520 °C would degrade aluminum. Examiner respectfully submits that this argument is **wholly without merit**, because it is clear that Luan performs the wet oxidation **before** the gate electrode is formed --not after. Luan also uses a temperature of 600 °C to perform the wet oxidation **before** the formation of the gate electrode. With Applicant's illogical reasoning, then, the Luan device would not work due to a degraded aluminum gate electrode, yet, quite to the contrary, Luan shows the device has excellent properties. Tseng was provided to show that one of ordinary skill in the art would use the presently claimed ratios of hydrogen to oxygen and steam to other total gases, since both Luan and Tseng are forming tantalum oxide by the same method (deposition followed by wet oxidation) for the same purpose: for gate dielectrics of a transistor.

For at least these reasons the arguments are not found persuasive.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to Erik Kielin whose telephone number is 571-272-1693. The examiner can normally be reached on 9:00 - 19:30.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Carl Whitehead, Jr. can be reached on 571-272-1702. The fax phone number for the organization where this application or proceeding is assigned is 703-872-9306.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free).



Erik Kielin
Primary Examiner
12 March 2004

APPENDIX A

HYDROGEN

HYDROGEN

CASRN: 1333-74-0

<http://toxnet.nlm.nih.gov/cgi-bin/sis/search/f?./temp/~/AAAxvaGVN:4>

Human Health Effects:

Human Toxicity Excerpts:

NO SPECIFIC TOXIC ACTION. IN HIGH CONCN CAN ACT AS A SIMPLE ASPHYXIANT.

[The Merck Index. 10th ed. Rahway, New Jersey: Merck Co., Inc., 1983. 695] **PEER REVIEWED**

Contact with liquid will cause frostbite or severe burns of the skin. Simple asphyxiant.

[Fire Protection Guide to Hazardous Materials. 12 ed. Quincy, MA: National Fire Protection Association, 1997., p. 49-76] **QC REVIEWED**

The relation between the /CNS depressant/ effect of nitrogen and that of hydrogen is 1:0.26.

[International Labour Office. Encyclopedia of Occupational Health and Safety. Vols. I&II. Geneva, Switzerland: International Labour Office, 1983. 1087] **PEER REVIEWED**

HYDROGEN HAS NO KNOWN TOXIC EFFECT ON THE EYE.

[Grant, W. M. Toxicology of the Eye. 2nd ed. Springfield, Illinois: Charles C. Thomas, 1974. 559] **PEER REVIEWED**

Animal Toxicity Studies:

Non-Human Toxicity Excerpts:

A LARGE BUBBLE OF THE GAS INJECTED INTO ANTERIOR CHAMBER OF RABBIT EYES WAS ABSORBED WITHIN THREE DAYS & CAUSED NO INJURY.

[Grant, W. M. Toxicology of the Eye. 2nd ed. Springfield, Illinois: Charles C. Thomas, 1974. 559] **PEER REVIEWED**

Metabolism/Pharmacokinetics:

Pharmacology:

Flamability: 4. 4= This degree includes flammable gases, pyrophoric liquids, and Class IA flammable liquids. The preferred method of fire attack is to stop the flow of material or to protect exposures while allowing the fire to burn itself out.

[Fire Protection Guide to Hazardous Materials. 12 ed. Quincy, MA: National Fire Protection Association, 1997., p. 325-59]**PEER REVIEWED**

Reactivity: 0. 0= This degree includes materials that are normally stable, even under fire exposure conditions, and that do not react with water. Normal fire fighting procedures may be used.

[Fire Protection Guide to Hazardous Materials. 12 ed. Quincy, MA: National Fire Protection Association, 1997., p. 325-59]**PEER REVIEWED**

Flammable Limits:

LOWER: 4.0%; UPPER: 75% (% BY VOL)

[Fire Protection Guide to Hazardous Materials. 12 ed. Quincy, MA: National Fire Protection Association, 1997., p. 325-59]**PEER REVIEWED**

Autoignition Temperature:

932 DEG F (500 DEG C)

[Fire Protection Guide to Hazardous Materials. 12 ed. Quincy, MA: National Fire Protection Association, 1997., p. 325-59]**PEER REVIEWED**

Fire Fighting Procedures:

Approach fire with caution as high-temperature flame is practically invisible. Stop flow of gas before extinguishing fire. Use water spray to keep fire-exposed containers cool. Use flooding quantities of water as fog or spray.

[Fire Protection Guide to Hazardous Materials. 12 ed. Quincy, MA: National Fire Protection Association, 1997., p. 49-76]**PEER REVIEWED**

Explosive Limits & Potential:

Lower: 4.1%; upper: 74.2%

[Lewis, R.J. *Sax's Dangerous Properties of Industrial Materials*. 9th ed. Volumes 1-3. New York, NY: Van Nostrand Reinhold, 1996. 1840]**PEER REVIEWED**

Severe, when exposed to heat or flame.

[Lewis, R.J. *Sax's Dangerous Properties of Industrial Materials*. 9th ed. Volumes 1-3. New York, NY: Van Nostrand Reinhold, 1996. 1840]**PEER REVIEWED**

Hazardous Reactivities & Incompatibilities:

Release of hydrogen @ 47.5 bar into a vented 17.5-l chromium-plated sphere caused explosive ignition. /Hydrogen/

[Bretherick, L. *Handbook of Reactive Chemical Hazards*. 4th ed. Boston, MA: Butterworth-Heinemann Heinemann Ltd., 1990, p. 1186-7]**PEER REVIEWED**

Hydrogen ignites in bromine fluoride at ambient temp.

[Bretherick, L. *Handbook of Reactive Chemical Hazards*. 4th ed. Boston, MA: Butterworth-Heinemann